COMPRESSOR HAVING AN ADJUSTABLE DIFFUSER WALL AND METHOD THEREFOR

FIELD OF THE INVENTION

The present invention relates generally to compressors and, more particularly, to a compressor with an adjustable diffuser for adjusting the configuration of a passage defined by the diffuser.

BACKGROUND OF THE INVENTION

Compressors, such as those used in turbochargers, typically include a compressor wheel that is rotatably mounted in a housing and that defines blades extending radially outward in proximity to an inner surface of the housing. The housing defines an inlet for receiving air or other gas, and an annular diffuser extends circumferentially around the housing to receive the air therefrom. A volute, disposed radially outward from the diffuser, is structured to receive the air from the diffuser. During operation, the air is compressed by the rotation of the blades of the compressor wheel and delivered radially outward through the diffuser to the volute. The compressor wheel is normally rotated at a high speed, such that the air is moved at a high velocity to the diffuser, which then slows the air and increases the static pressure of the air. In the volute, which provides a relatively large volume compared to the diffuser, the velocity of the air is further reduced and the static pressure of the air is also increased.

Preferably, the compressor can be used over a range of operating pressures. For example, a compressor used in a turbocharger may be operated over a range of speeds and pressures depending on the operating mode of an engine with which the turbocharger is used. However, the operating range of the compressor and, hence, the turbocharger, is typically limited by two phenomena

referred to as surging and choking. Surging refers to a condition in which a low volumetric flow of air through the compressor and a high pressure difference between the inlet and the outlet of the compressor result in "stalling" of the compressor and a periodic reversing flow from the outlet to the inlet. Choking refers to a condition in which the velocity of air inside the inducer portion of the compressor reaches sonic velocity and cannot be increased further by the compressor.

Some conventional compressors include a surface in the diffuser that can be moved relative to an opposed fixed surface in the diffuser, thereby varying the capacity of the compressor and stabilizing the operation of the compressor to avoid surging. The movable surface can be moved by a drive mechanism as required for stabilizing the flow of the gas through the compressor. However, such drive mechanisms add to the complexity of the compressor, thereby increasing the costs associated with manufacturing and operating the device.

Thus, there exists a continued need for an improved compressor and diffuser therefor, such as can be used with turbochargers and other devices requiring the compression of air or other fluids. The compressor should be capable of being operated over a range of pressures and/or speeds without stalling or choking.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

Figure 1 is a section view illustrating a compressor having an adjustable diffuser according to one embodiment of the present invention;

Figure 2 is a partial section view illustrating the compressor of Figure 1 with the diffuser wall shown in an open position;

Figure 3 is a partial section view illustrating the compressor of Figure 1 with the diffuser wall shown in a closed position;

Figure 4 is partial section view illustrating a diffuser wall according to another embodiment of the present invention, shown in an open position;

Figure 5 is a partial section view illustrating the diffuser wall of Figure 4, shown in a closed position;

Figure 6 is a graph illustrating the operating ranges of a compressor as a function of pressure, speed, and air flow according to one embodiment of the present invention;

Figure 7 is partial section view illustrating the adjustable diffuser wall of the compressor of Figure 1 with a control valve according to one embodiment of the present invention, the control valve being shown in a first position; and

Figure 8 is a partial section view illustrating the adjustable diffuser wall and control valve of Figure 7 with the control valve in a second position.

DETAILED DESCRIPTION OF THE INVENTION

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the invention are shown. Indeed, this invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like numbers refer to like elements throughout.

Referring to Figure 1, there is shown a compressor **10** with an adjustable diffuser **30** according to one embodiment of the present invention. The compressor **10** can be used for delivering and compressing a variety of fluids, and the compressor **10** can be used in conjunction with various devices and applications. For example, the compressor **10** can be coupled to a turbine of a turbocharger for a combustion engine and used to provide compressed air for combustion in the engine.

As shown in Figure 1, the compressor **10** includes a compressor wheel **12** disposed in a compressor wheel housing **14**. The wheel **12** is rotatably mounted in the housing **14** on a shaft **16** that extends from the housing **14**, e.g., through a center housing and to a turbine of a turbocharger (not shown). Thus, the wheel **12** is configured to be rotated in the housing **14** by the shaft **16**. A plurality of blades **18** extend radially outward from the compressor wheel **12**, and the blades **18**

extend proximate to a contoured inner surface **20** of the housing **14** so that the compressor wheel **12** can be used to deliver air through the housing **14**. More particularly, the compressor wheel **12** is configured to draw air into the housing **14** through an inlet **24** and deliver the air to a body of the diffuser **30** and a volute **26** of the compressor **10**. The compressed air can be delivered from the volute **26** through an outlet (not shown).

The diffuser **30** extends circumferentially around the compressor wheel housing **14** and defines a fluid passage **32** connected to the housing **14**. The volute **26** extends circumferentially around the diffuser **30** and is configured to receive the air from the housing **14** via the diffuser **30**. All or part of the diffuser **30** and volute **26** can be formed integrally with the compressor wheel housing **14**, and the diffuser **30** can correspond in size and shape to a center housing of a turbocharger or another device for connection thereto. For example, the housing **14** can include a backplate **15** that is bolted or otherwise attached to the rest of the housing **14**, and the backplate **15** can be connected to the center housing or other device.

The passage **32** of the diffuser **30** is defined by a stationary inner surface **34** and an adjustable diffuser wall **36** disposed in the diffuser **30**. The adjustable diffuser wall **36** extends circumferentially in the diffuser **30**, i.e., in a partial or complete annular configuration. As shown in Figure 2, a first side **38** of the diffuser wall **36** is directed toward the inner surface **34** of the diffuser **30**. A second side **39** of the diffuser wall **36**, which is opposite the first side **38**, is actuated by a control fluid provided through a fluid port **40**. For example, the adjustable diffuser wall **36** can be disposed in an annular recess **42** or other space provided in the diffuser **30** opposite the inner surface **34** and configured to be adjusted out of the recess **42** toward the inner surface **34**. Thus, by adjusting the diffuser wall **36** relative to the inner surface **34** of the diffuser **30**, a gap defining the passage **32** between the diffuser wall **36** and the inner surface **34** can be changed.

Figures 2 and 3 illustrate the adjustment of the diffuser wall **36** according to one embodiment of the present invention. The adjustable diffuser wall **36** is connected to a first side **46** of a diaphragm **44**, which can be formed of a

deformable material such as an elastomeric sheet. For example, the adjustable diffuser wall **36** can be connected to the diaphragm **44** by rivets **49** or other connectors. The diaphragm **44** extends circumferentially in the recess **42**, and radially inner and outer peripheral portions **50, 52** of the diaphragm **44** can be connected to radially inner and outer sides **54, 56** of the recess **42**. A second side **48** of the diaphragm **44**, opposite the first side **46**, is therefore in fluid communication with the fluid port **40**.

The fluid port **40** is configured to receive the control fluid such that the control fluid is delivered to the recess **42** and provides a force on the diaphragm **44** and, hence, the adjustable diffuser wall **36**, in the direction of the inner surface **34** of the diffuser **30**. If the pressure of the control fluid in the recess **42** is greater than the pressure of the gas in the passage **32** of the diffuser **30**, the adjustable diffuser wall **36** is urged toward the inner surface **34**, thereby reducing the size of the gap defining the passage **32** as shown in Figure 3. Alternatively, if the pressure of the control fluid in the recess **42** is less than the pressure of the gas in the passage **32**, the adjustable diffuser wall **36** is urged away from the inner surface **34**, i.e., into the recess **42**, thereby increasing the size of the gap defining the passage **32** as shown in Figure 2. One or more projections or stops **58, 59** can be provided on the adjustable diffuser wall **36** and/or the diaphragm **44** to limit the motion of the wall **36**. That is, when the diffuser wall **36** is urged toward the inner surface **34** (Figure 3), first stops **58** on the diffuser wall **36** can be pushed into contact with the inner surface **34** so that the diffuser wall **36** is adjusted to a first, or closed, position, in which a reduced flow of the gas can be maintained through the passage **32** to the volute **26**. Similarly, when the diffuser wall **36** is urged away from the inner surface **34** (Figure 2), second stops **59** on the diffuser wall **36** can be pushed into contact with the inner surface **34** so that the diffuser wall **36** is adjusted to a second, or open, position.

While the radially inner and outer peripheral portions **50, 52** of the diaphragm **44** are shown to be connected to the diffuser **30** in Figures 2 and 3, it is appreciated that the diffuser wall **36** can alternatively be supported in various other configurations. For example, as shown in Figures 4 and 5, the outer peripheral portion **52** of the diaphragm **44** can be connected to the radially outer

side **56** of the recess **42**, and the inner peripheral area **50** can be connected to a first sealing member **60**. The first sealing member **60** corresponds to a second sealing member **62** provided at the radially inner side **54** of the recess **42** so that the first and second sealing members **60, 62** form a seal therebetween as the first sealing member **60** is adjusted with the adjustable diffuser wall **36** in sliding contact with the second sealing member **62**. Thus, the adjustable diffuser wall **36** can be adjusted between a first, or closed, position (Figure 5) and a second, or open, position (Figure 4). In the open position, the first sealing member **60** can be adjusted against the recess **42** as shown in Figure 4 so that the sealing member **60** acts as a stop to limit the adjustment of the diffuser wall **36**.

By adjusting the size of the gap defining the passage **32** in the diffuser **30**, the cross-sectional size of the passage **32** can be increased or decreased. Thus, the adjustable diffuser wall **36** provides an adjustable cross-sectional flow area for the passage **32**, as can be appropriate for different air mass flow rates through the diffuser **30**. Advantageously, the operating range of the compressor **10** can be extended by adjusting the size of the passage **32**. For example, at times when the compressor **10** is subject to stalling due to a low volumetric flow of air through the compressor **10**, the adjustable diffuser wall **36** can be adjusted to the closed position to decrease the required flow rate at which the compressor **10** will stall. Alternatively, when the compressor **10** is subject to a higher mass flow rate of the air entering the compressor **10** at a high velocity, the adjustable diffuser wall **36** can be adjusted to the open position to decrease the surface friction of air through the diffuser **30** and, hence, increase the efficiency of the compressor **10**. In other embodiments of the present invention, the diffuser **30** can be adjusted at different times, according to other operational parameters, and/or to achieve other operational results.

Figure 6 is a graph illustrating the operating ranges **90a, 90b** of a compressor according to one embodiment of the present invention. As illustrated, the extent of each operating range **90a, 90b** of the compressor **10** is dependent on the mode in which the compressor **10** is operating, i.e., with the diffuser **30** closed or open. The left-most edge **92a, 92b** of each operating range **90a, 90b** indicates the operating points at which the compressor **10** is subject to stalling. The

rightmost edge **94a, 94b** of each operating range **90a, 90b** indicates the operating points at which the compressor **10** is subject to choking. Thus, the area within each operating range **90a, 90b** indicates the operating conditions under which the compressor **10** can be operated with little risk of stalling or choking. In addition, the operating efficiency of the compressor **10** generally increases near the center of each operating range **90a, 90b** as indicated by the percent efficiency values shown on the graph. Curved lines extending across each operating range indicate the operating speed of the compressor **10**, between 80,000 and 180,000 revolutions per minute (RPM) in the illustrated embodiment.

The operating ranges **90a, 90b** for the two modes of operation are not co-extensive. More particularly, the range **90a** of the compressor **10** in the first mode of operation, in which the diffuser **30** is closed, generally extends further to the left in the graph. The range **90b** of the compressor **10** in the second mode of operation, in which the diffuser **30** is open, extends further to the right in the graph. For example, at point **100** in the first operating range **90a**, a pressure ratio of the compressor **10**, i.e., the pressure exiting the volute **26** divided by the pressure of the atmosphere, is equal to about 1.8, and the compressor **10** is rotating at a speed of about 120,000 RPM, resulting in a flow of air through the compressor **10** at a first rate. Point **100** is within the operating range **90a** of the compressor **10** for the first mode of operation (diffuser **30** closed) but is outside the operating range **90b** for the second mode of operation (diffuser **30** open). Alternatively, at point **102** of the second operating range **90b**, the pressure ratio is 1.8 and the compressor **10** is rotating at a speed of about 160,000 RPM. Point **102** is within the operating range **90b** of the compressor **10** for the second mode of operation (diffuser **30** open) but is outside the operating range **90a** for the first mode of operation (diffuser **30** closed). Thus, the compressor **10** can be operated in an extended, or combined, operating range by closing the diffuser **30** when the compressor **10** is operating at low air flow rates and opening the diffuser **30** when the compressor **10** is operating at high air flow rates. Within those ranges where the operating ranges overlap **90a, 90b**, i.e., where the compressor **10** can be operated with the diffuser **30** open or closed, the diffuser **30** can be adjusted to the

mode for which the operating efficiency is higher for the current operating conditions.

The control fluid can be provided through a selection valve **70** configured to adjust the pressure thereof, as illustrated in Figures 7 and 8. For example, the selection valve **70** can be configured to selectively provide the pressurized gas from one of two fluid sources **72, 74**. The first fluid source **72** can be a vent to an ambient source, e.g., the ambient air in the operating environment of the compressor **10**, which provides atmospheric pressure. The second fluid source **74** can be the volute **26**, which is typically pressurized with air having a static pressure higher than the pressure in the diffuser **30**. Thus, in a first mode of operation (Figure 8), the volute pressure is provided through the selection valve **70**, and the diffuser wall **36** is urged to the first position, thereby minimizing the cross-sectional flow area of the diffuser **30**. In a second mode of operation (Figure 7), the air at atmospheric pressure is provided through the selection valve **70**, and the diffuser wall **36** is urged to the second position, thereby maximizing the cross-sectional flow area of the diffuser **30**. The selection valve **70** can be controlled by a mechanical or electrical controller (not shown) that senses operating parameters of the compressor **10** and adjusts the valve **70** accordingly. Such operating parameters can include the pressure or velocity of the air in different portions of the compressor **10**, the speed of the wheel **12**, and operating parameters of devices external to the compressor **10**. For example, according to one embodiment of the present invention, the diffuser **30** is used in conjunction with a turbocharger for a combustion engine, which operates through a range of rotation speeds, the speed of the engine generally being correlated to the air flow rate through the compressor **10**. The diffuser **30** can be closed at low engine speeds, such as below about 2000 RPM, and opened at higher engine speeds. Thus, the operating range of the compressor **10** is extended such that the turbocharger can be used to provide torque at low engine speeds. Further, the efficiency of the compressor **10** can be improved by selectively operating the compressor **10** in the mode that is most efficient for any given operating conditions.

It is appreciated that different control fluids from alternative sources can be provided for adjusting the diffuser wall **36**. For example, pressurized air or other gases can be provided from other portions of the compressor **10** or from other components of a turbocharger or engine operated in conjunction with the compressor **10**. Further, the control fluid can be an intermediate fluid in communication with the fluids from the fluid sources **72, 74**, i.e., such that the fluids from the fluid sources **72, 74** provide pressure to the diffuser wall **36** via the control fluid without the fluids from the fluid sources being delivered directly to the diffuser wall **36**.

Many modifications and other embodiments of the invention set forth herein will come to mind to one skilled in the art to which this invention pertains having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.